EDUCATOR EDITION *AP Physics*

SPACE EXPLORATION AP

LUNAR SURFACE INSTRUMENTATION

Instructional Objectives

Students will

- add, subtract, and resolve displacement and velocity vectors to determine components of a vector along two specified, mutually perpendicular axes; and
- determine the net displacement of a particle or the location of a particle relative to another.

Degree of Difficulty

This problem is a straightforward application of vector concepts.

- For the average AP Physics student, the problem may be moderately difficult.

Background

This problem is part of a series of problems that apply physics principles to NASA's Vision for Space Exploration.

Exploration provides the foundation of our knowledge, technology, resources, and inspiration. It seeks answers to fundamental questions about our existence, responds to recent discoveries and puts in place revolutionary techniques and capabilities to inspire our nation, the world, and the next generation. Through NASA, we touch the unknown, we learn and we understand. As we take our first steps toward sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future.

The Vision for Space Exploration includes returning the space shuttle safely to flight, completing the International Space Station, developing a new exploration vehicle and all the systems needed for embarking on extended missions to the Moon, Mars, and beyond.

Lunar outpost concepts are now being designed and studied by engineers, scientists, and sociologists to facilitate long-duration human missions to the surface of the Moon (Figure 1). Such lunar outposts will include habitat modules, laboratory modules, power systems, transportation, life support systems, protection from the environment, communications for lunar surface operations, and communications between the Moon and Earth.

Supplemental Problem for AP Physics

Grade Level
11-12

Key Topic
Vector Addition

Degree of Difficulty
Physics B,C: Moderate

Teacher Prep Time
5 minutes

Problem Duration
30 minutes

Technology
Graphing Calculator

Materials
Student Edition including:
- Background handout
- Problem worksheet

NSES
Science Standards
- Science and Technology
- History and Nature of Science

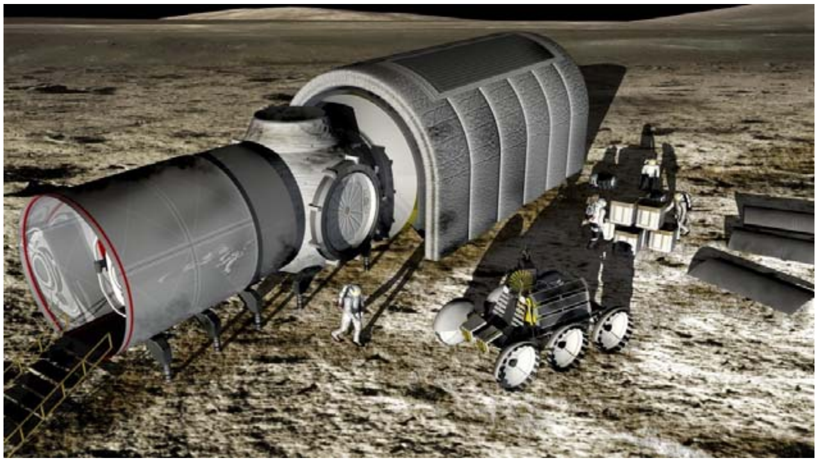

Figure 1: Lunar habitat, airlock, and vehicles (NASA concept)

During past space missions, astronaut activity outside of the vehicle (e.g. space shuttle) was referred to as an extravehicular activity, or EVA. In a similar way, extrahabitat activities, or EHA, will be performed during a lunar mission to accomplish exploration work. One EHA may be to place environmental sensors and instruments within the proximity of a lunar outpost (Figure 2).

Figure 2: Astronaut services a lunar-surface instrument (NASA concept)

Such instruments may measure the radiation received from solar flares or characterize micrometeorites impacting the lunar surface. Telescopes may also be set up for observations of Earth, planets, and stars.

For more information about lunar outposts and the Vision for Space Exploration, visit www.nasa.gov.

NSES Science Standards

Science and Technology

Abilities of Technological Design

- Implement a proposed solution.
- Evaluate the solution and its consequences.
- Communicate the problem, process, and solution.

History and Nature of Science

Science as a Human Endeavour

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise.

Problem

An astronaut services three instruments on the relatively flat lunar surface around an equatorial lunar outpost. She starts at the lunar habitat airlock and walks 180 meters southwest to replace the sample cell in the first instrument. She then walks 140 meters due north to add a lens to a second instrument. She finishes the task by walking 100 meters 30 degrees north of east where she resets the pointing of a third instrument. The astronaut walks directly back to the same habitat airlock and reenters the habitat module. Using a Cartesian coordinate system with the *x*-axis pointed east and *y*-axis pointed north, determine the following information for her EHA.

Round all answers to one decimal place.

1. Determine the astronaut's displacement vector (distance and direction) from the airlock when she is standing at each instrument.

2. Determine her displacement (using unit-vector notation) from the airlock when she is standing at each instrument.

3. Determine the astronaut's displacement from the first instrument and the third instrument.

4. Determine the distance she walked from the third instrument to the habitat airlock.

5. Determine the total distance she traveled on her EHA.

6. Why is it important to use vector analysis for this solution?

Solution Key (One Approach)

1. Determine the astronaut's displacement vector (distance and direction) from the airlock when she is standing at each instrument.

   Step 1: Sketch the path taken by the astronaut.

   Place the coordinate system origin at the airlock door.

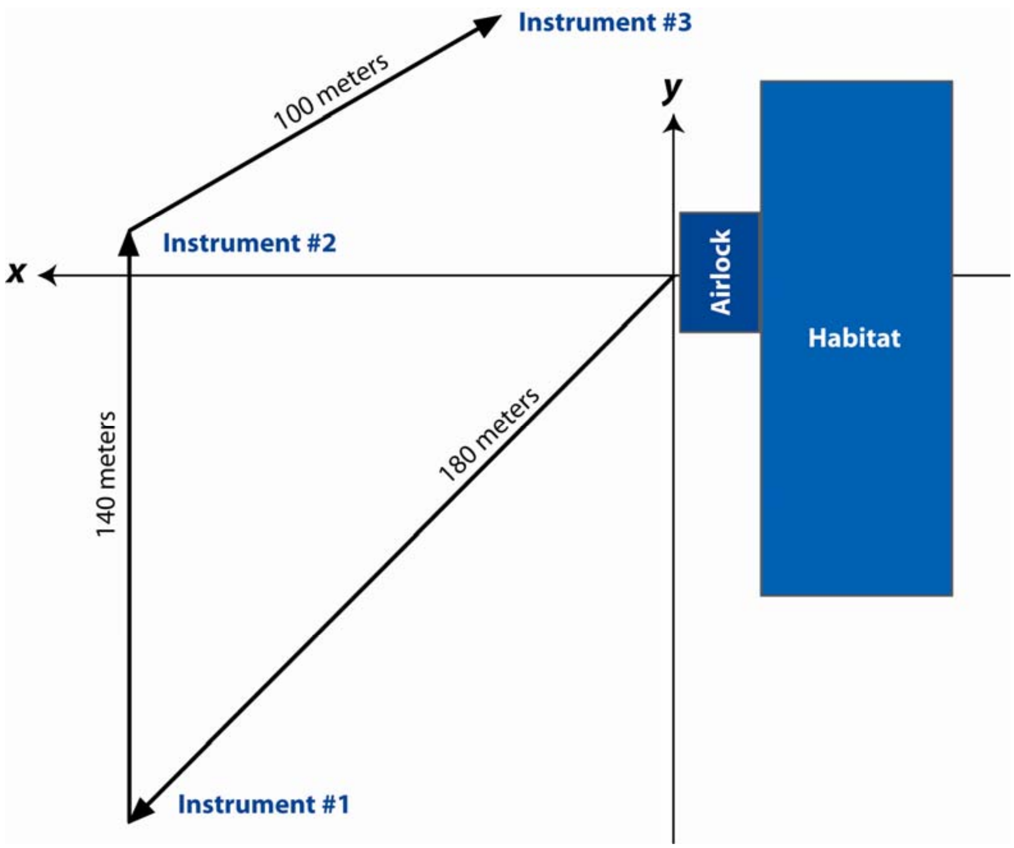

Figure 3: Locations of the lunar surface instruments

   Step 2: Determine the *(x,y)* components of each leg of the trip.

   First Leg:

$$x = 180\,cos(225°) = -127.3\text{ m}$$
$$y = 180\,sin(225°) = -127.3\text{ m}$$

   Second Leg:

$$x = 140\,cos(90°) = 0.0\text{ m}$$
$$y = 140\,sin(90°) = 140.0\text{ m}$$

Third Leg:

$$x = 100\,cos(30°) = 86.6\text{ m}$$

$$y = 100\,sin(30°) = 50.0\text{ m}$$

Step 3: Determine the *(x,y)* position of each instrument.

Add successive legs of the trip as vector components.

First leg from the origin to instrument #1:

$$x = 0.0\text{ m} + (-127.3\text{ m}) = -127.3\text{ m}$$

$$y = 0.0\text{ m} + (-127.3\text{ m}) = -127.3\text{ m}$$

Instrument #1 location: $(-127.3, -127.3)\text{ m}$

Second leg from instrument #1 to instrument #2:

$$x = -127.3\text{ m} + 0.0\text{ m} = -127.3\text{ m}$$

$$y = -127.3\text{ m} + 140.0\text{ m} = 12.7\text{ m}$$

Instrument #2 location: $(-127.3, 12.7)\text{ m}$

Third leg from instrument #2 to instrument #3:

$$x = -127.3\text{ m} + 86.6\text{ m} = -40.7\text{ m}$$

$$y = 12.7\text{ m} + 50.0\text{ m} = 62.7\text{ m}$$

Instrument #3 location: $(-40.7, 62.7)\text{ m}$

2. Determine her displacement (using unit-vector notation) from the airlock when she is standing at each instrument.

   Since the three vectors are from the origin to the three instruments, convert the position *(x,y)* values to vector notation using unit vectors.

Instrument #1: $(-127.3i - 127.3j)\text{ m}$

Instrument #2: $(-127.3i + 12.7j)\text{ m}$

Instrument #3: $(-40.7i + 62.7j)\text{ m}$

3. Determine the astronaut's displacement from the first instrument and the third instrument.

   Step 1: Find the distance between instruments #1 and #3 using the distance formula.

$$d = \sqrt{(y_3 - y_1)^2 + (x_3 - x_1)^2}$$

$$d = \sqrt{(62.7 - (-127.3))^2 + ((-40.7) - (-127.3))^2}$$

$$d = 208.8 \text{ m}$$

   Step 2: Find the angle between instruments #1 and #3 using the inverse tangent function.

$$\angle\theta = tan^{-1}\left(\frac{x_3 - x_1}{y_3 - y_1}\right)$$

$$\angle\theta = tan^{-1}\left(\frac{-40.7 - (-127.3)}{62.7 - (-127.3)}\right) = 24.5°$$

   Instrument #3 is 208.8 m and 24.5° east of north from instrument #1.

4. Determine the distance she walked from the third instrument to the habitat airlock.

$$d = \sqrt{(y_0 - y_3)^2 + (x_0 - x_3)^2}$$

$$d = \sqrt{(0 - 62.7)^2 + (0 - (-40.7))^2}$$

$$d = 74.8 \text{ m}$$

5. Determine the total distance she traveled on her EHA.

First Leg:	180.0 m
Second Leg:	140.0 m
Third Leg:	100.0 m
Fourth Leg:	74.8 m

   Sum of the four individual leg lengths.

$$d = 180.0 + 140.0 + 100.0 + 74.8 = 494.8 \text{ m}$$

6. Why is it important to use vector analysis for this solution?

   Answers will vary, but should include that vector analysis is an optimum way to graphically display the location of the instruments and their positions in respect to the airlock.

Contributors

Thanks to the subject matter experts for their contributions in developing this problem:

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Space Exploration AP – Lunar Surface Instrumentation

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Or type your responses in an email and send to: Monica.Trevathan-1@nasa.gov

Please circle the appropriate response.

1. This problem was useful in my classroom. YES NO

2. The problem successfully accomplished the stated Instructional Objectives. YES NO

3. I will use this problem again. YES NO

4. Please provide suggestions for improvement of this problem and associated material:

5. Please provide suggestions for future AP Physics problems, based on NASA topics, that you would like to see developed:

Thank you for your participation.

Please fax this completed form to Monica Trevathan at (281) 461-9350.